



Damping Ring Design and ATF Report

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Overview



- LBNL Staff for NLC Damping Ring Design
 - Alan Jackson (Lead)
 - Stefano de Santis, Andy Wolski (Accelerator Physics)
 - Kurt Kennedy (Vacuum)
 - Jin-Young Jung, Steve Marks (Magnets)
 - Mauro Pivi (Electron Cloud)
- Contents of Talk
 - TRC
 - program for Damping Rings
 - status and plans
 - impact on Damping Rings work
 - Recent Developments in NLC Damping Rings
 - estimates of collective effects in Main Damping Rings
 - Experimental program: ATF
 - Beam-Based Alignment
 - Damping Rings R&D program



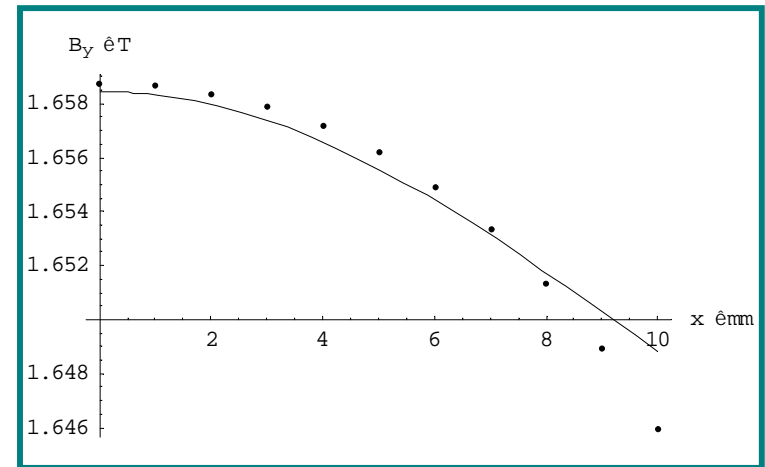
- Group Members:
 - Joe Rogers (leader)
 - Ralph Assmann
 - Winfried Decking
 - Jacques Gareyte
 - Kiyoshi Kubo
 - Andy Wolski
- Tasks:
 - Define wiggler models
 - Define misalignment and magnet error models
 - Define diagnostic and correction models
 - Evaluate emittances with misalignments and tuning algorithms
 - Evaluate effect of IBS on extracted emittances
 - Evaluate effects of impedance, ions, electron cloud
 - Evaluate effect of extraction kicker on emittances
 - Evaluate particle loss
 - Evaluate extracted beam stability (against jitter)
 - Evaluate preservation of polarization



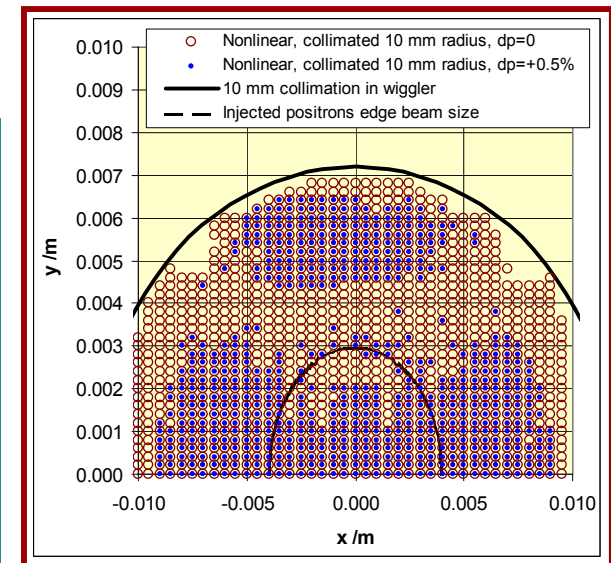
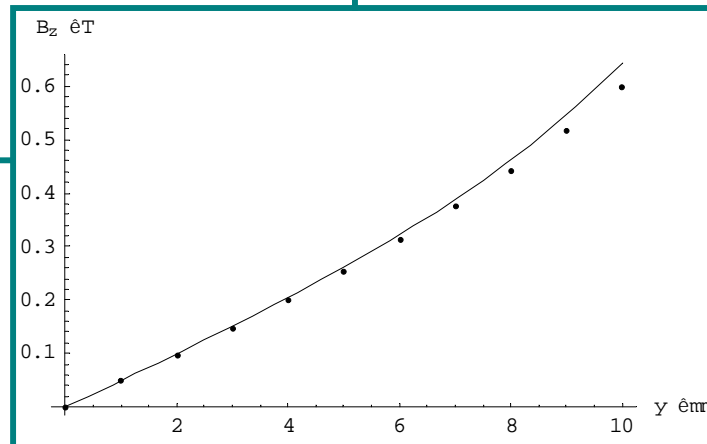
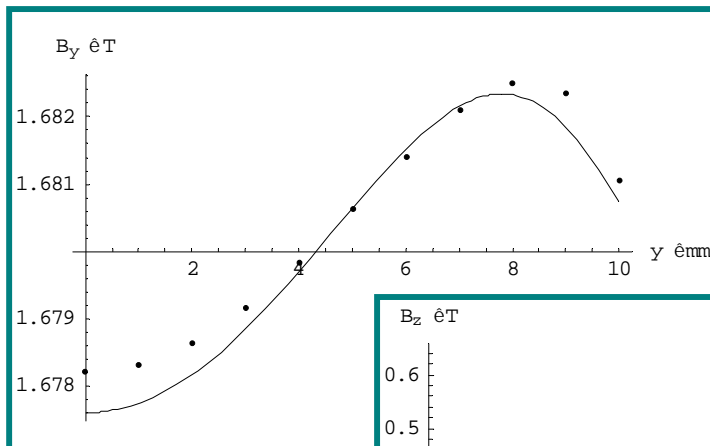
TRC Wiggler Models



- 3-D field fit for a single period
- Use expansion in symplectic integrator
 - some approximations needed
- Determine dynamic aperture
- Track with “actual” bunch to determine injection efficiency



Sample fits and DA for TESLA

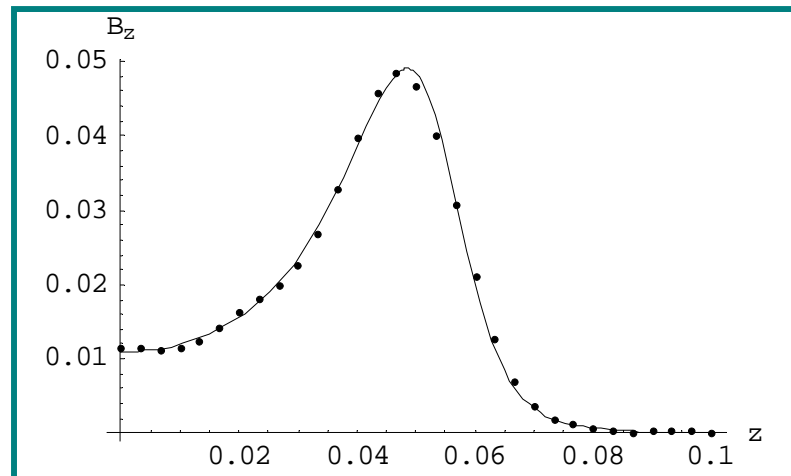
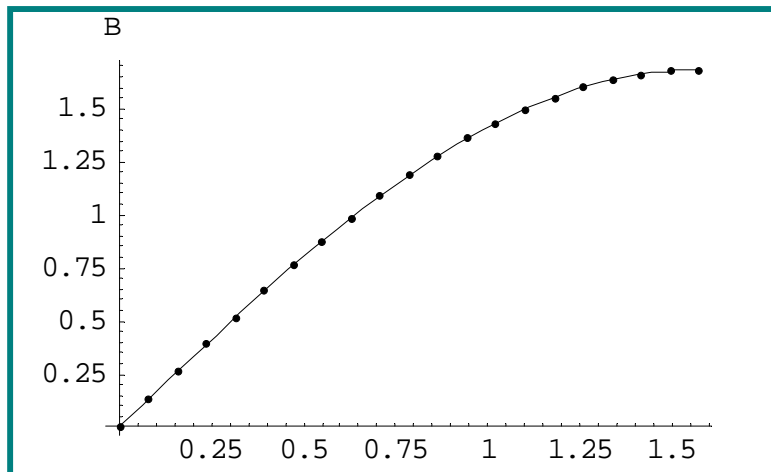




TRC Wiggler Models



- TESLA DRs have >400 m of wiggler
 - provide 90% of energy loss
 - significant effect on the dynamics
- Improved fitting and modeling procedure is motivated
 - recently started working with Alex Dragt
 - already have much easier and more robust field fitting algorithm
 - exploring best approach for constructing a dynamical map through the wiggler
- Results will be very useful for NLC (and light sources...)





TRC

Emittance Tuning Simulations

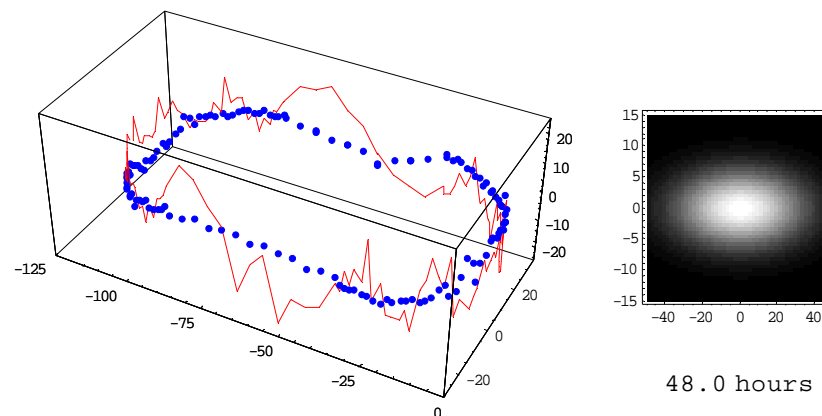
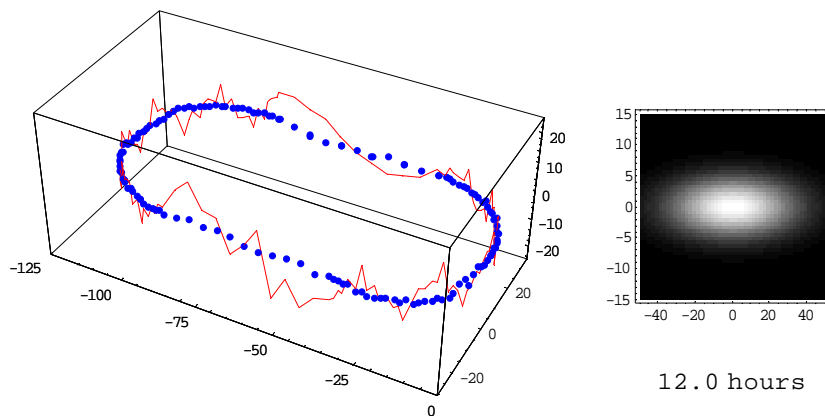
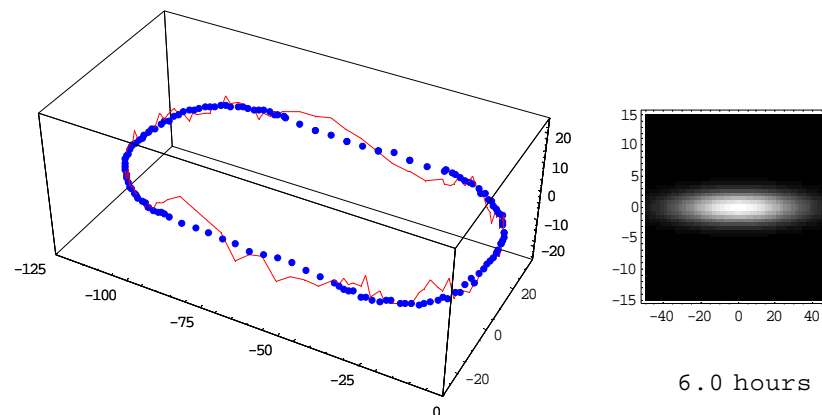
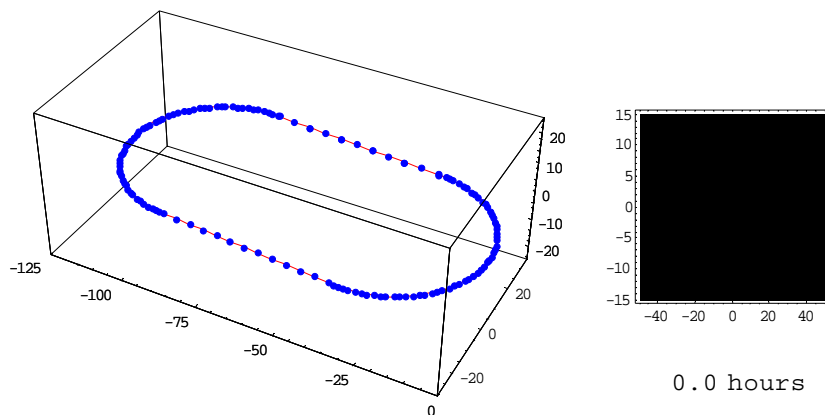


- Report will refer to ATF experience
- Cross-checked emittance tuning algorithms between MAD/MATLAB (DESY) and MERLIN (LBNL)
 - NLC and TESLA use algorithms based on orbit and dispersion correction
 - NLC algorithm performs satisfactorily with tight tolerances
 - $\sim 100 \mu\text{m}$ initial alignment on quadrupoles and sextupoles
 - $\sim 100 \mu\text{rad}$ roll errors on quadrupoles
 - $<1 \text{ mm}$ rms vertical dispersion correction, requires $0.3 \mu\text{m}$ BPM resolution
 - correction achieved in 90% of cases
 - Further work needed on TESLA correction
 - chromaticity correction is local to the arcs (extreme for TESLA DR structure)
 - using sextupoles to correct dispersion globally introduces strong betatron coupling
- Developed 2D ATL model and implemented in simulations
 - allows consistent use of ground motion models across entire LC
 - study tuning performance in better approximation to reality
 - could be important for TESLA



TRC

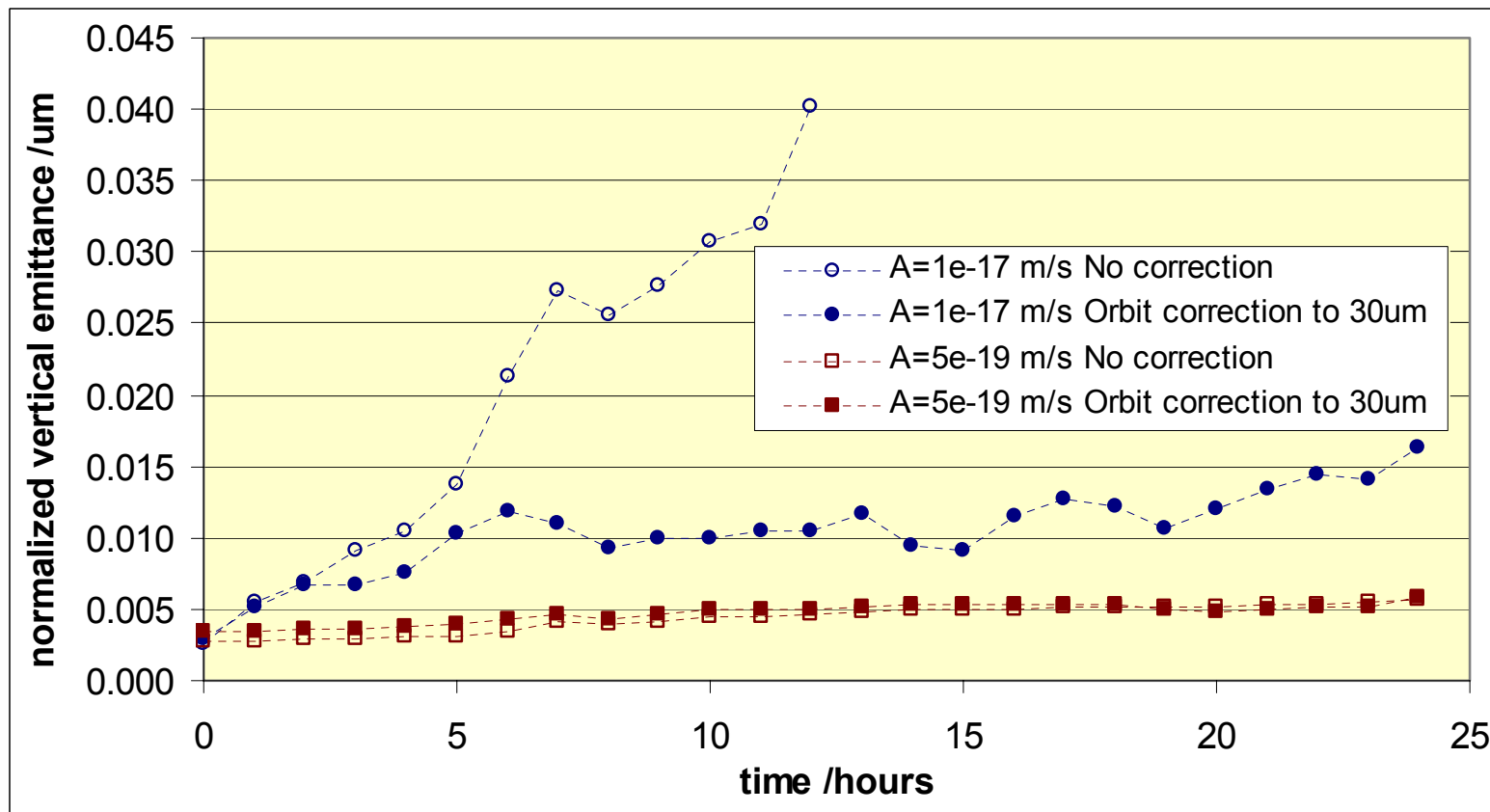
Emittance Tuning Simulations





TRC

Emittance Tuning Simulations





TRC

Collective Effects



- Studies in progress (see later slides)
- Impedance effects
 - TESLA and NLC will operate satisfactorily with specified impedance...
 - ...but specifications are very tight and great care will be needed in vacuum chamber design and construction
- Space-Charge
 - implications of TESLA coupling scheme still not fully explored by TRC
 - space-charge tune shift not entirely negligible in NLC MDR
 - simulations required
- Electron Cloud
 - a significant issue for NLC MDR and TESLA
- Fast Ion Instability
 - needs more study
- Intra-Beam Scattering
 - TESLA probably OK
 - an issue for NLC MDR, studies ongoing...



TRC Impact



- Closer collaboration between projects
 - discussion of common issues, e.g. emittance tuning, collective effects
 - cross-checking of codes and results
- Further development of existing models
 - wiggler work
- Consistency with other systems in LC
 - ground motion models
 - component performance specifications (BPM resolution...)
- Accelerated timescales
 - effects of kickers, jitter etc.



NLC Damping Rings Status



- Lattice designs are stable
 - Main Damping Rings, Pre-Damping Ring, Transport Lines
 - Meet acceptance and damping specifications
 - All main systems and components included in designs
- Algorithm developed for Low-Emittance Tuning
 - Alignment tolerances and BPM resolutions have been determined by analytical studies and simulations
- Systems and component designs
 - RF cavities
 - Main Damping Ring wiggler
 - Dipoles and quadrupoles for Main Damping Ring
 - Permanent Magnet and Electromagnet technologies have been considered
 - Vacuum chamber
- Engineering designs
 - Design work has shown practicality of Accelerator Physics design

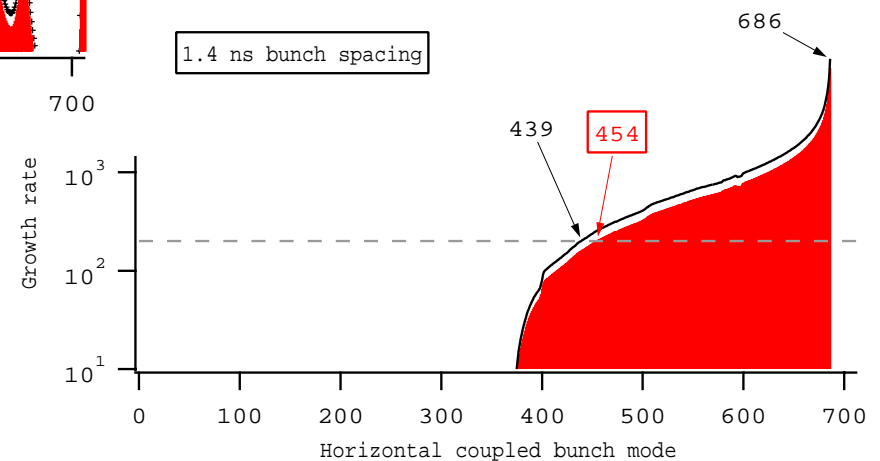
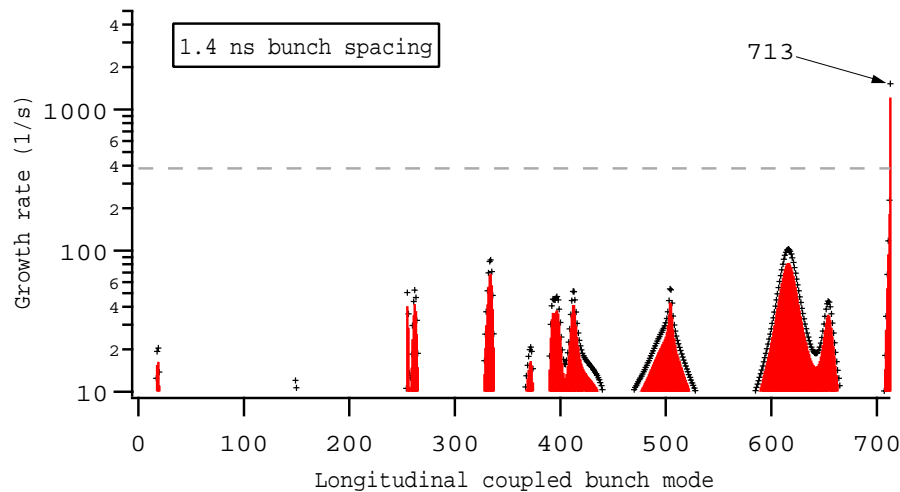


NLC MDR Collective Effects



- Recent (and ongoing) focus of NLC DR studies
- Various effects need to be considered:
 - Long-Range Wake Fields
 - Short-Range Wake Fields
 - Touschek Scattering
 - Intra-Beam Scattering
 - Phase Transients from Beam Loading
 - Electron Cloud
 - single bunch
 - coupled bunch
 - Fast Ion Instability

- Studies by Stefano de Santis
- Transverse dominated by resistive wall
- Feedback system with bandwidth ~ 350 MHz required

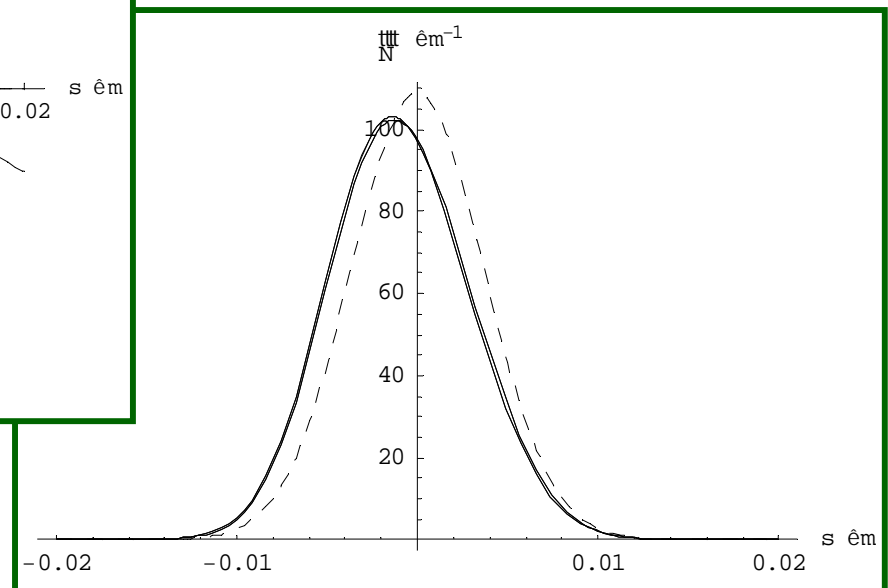
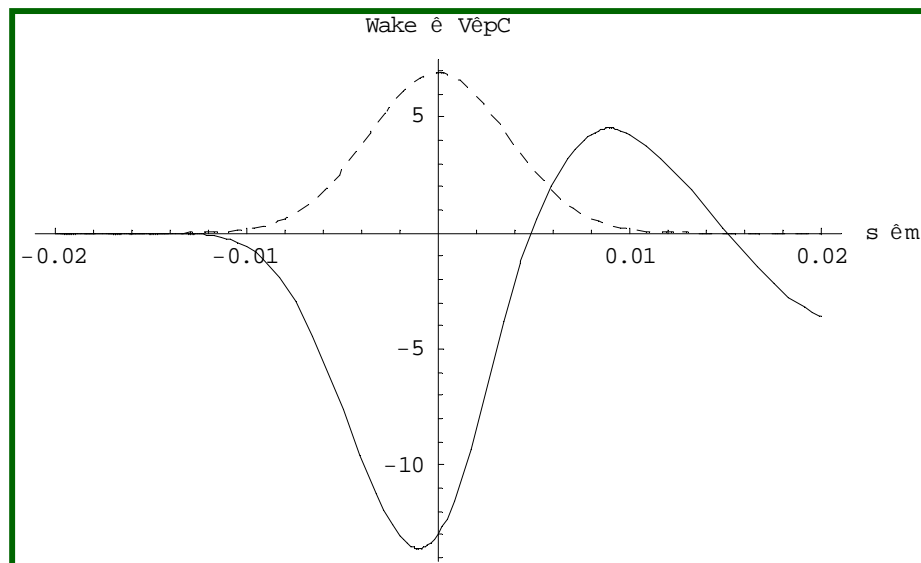




Short-Range Wake Fields



- Impedance model by Cho Ng (1999)
- Potential Well Distortion is a small effect ($\sim 5\%$)
- $Z/n = 25 \text{ m}\Omega$ (mostly resistive)
 - apply Boussard criterion to estimate microwave threshold
 - bunch charge roughly a factor of three below threshold

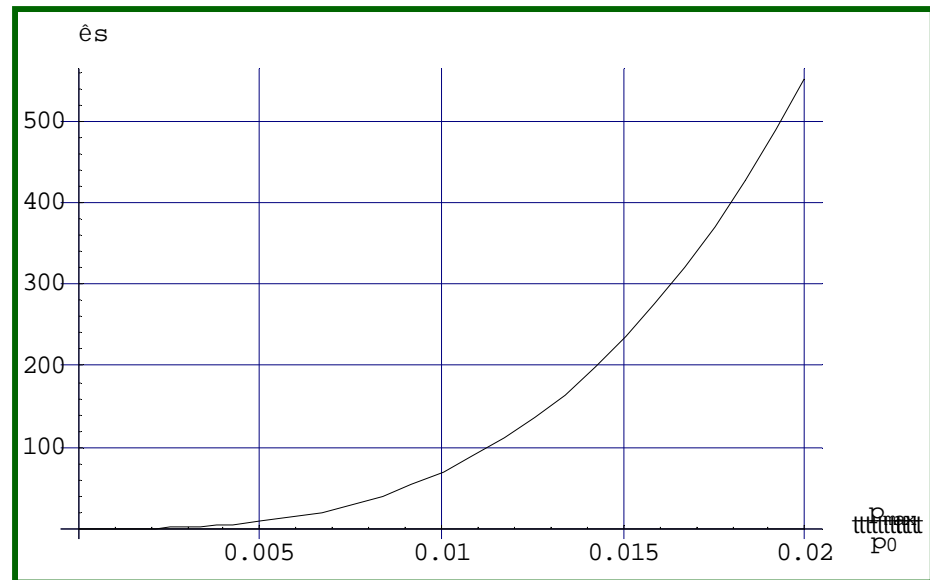




Touschek Lifetime



- Expect around 4 minutes with nominal parameters
 - An issue for commissioning and tuning
 - Potential heat load by particle loss (expect only $\sim 10\text{W}$ from this mechanism)
- Lifetime can be improved by:
 - improving momentum acceptance
 - coupling the beam

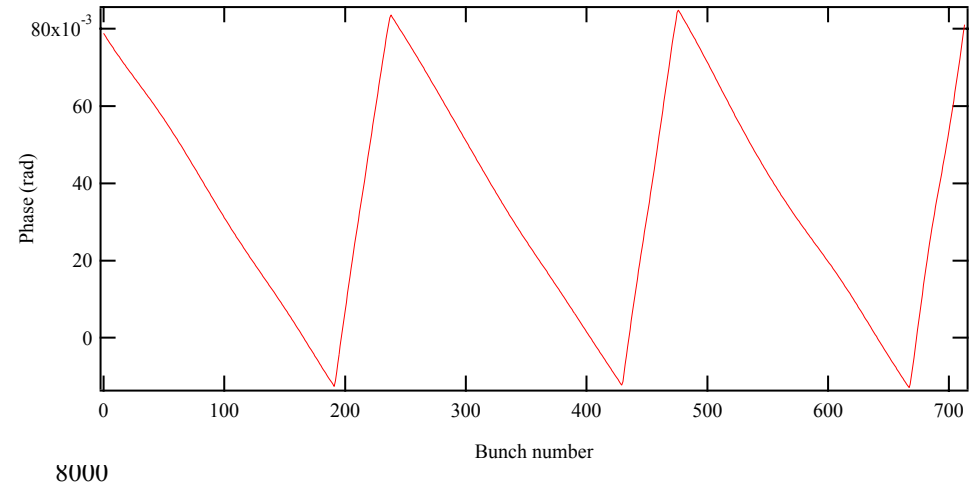
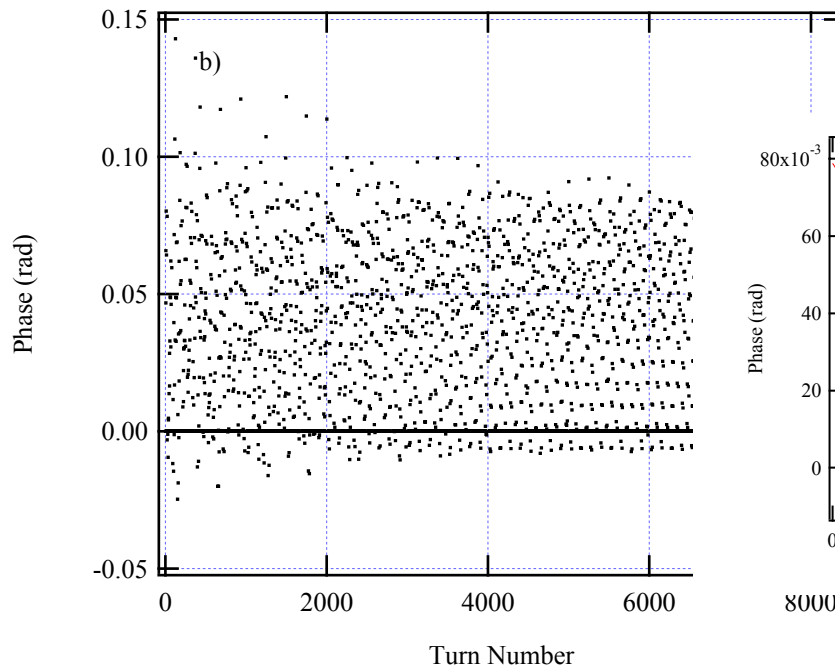




Phase Transients



- Beam loading in RF cavities gives phase shift along the train
 - studied by tracking (Stefano de Santis; simulation code from John Byrd)
- Tolerances set by bunch compressors
- Effects from main cavities are not too severe
 - linear phase variation along the train

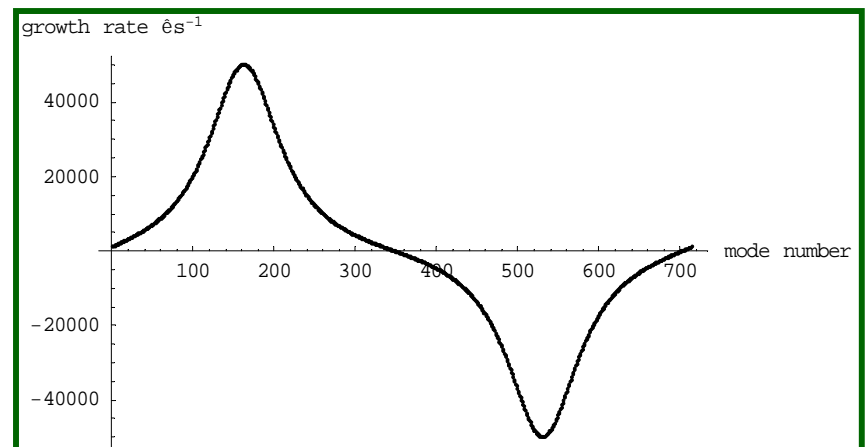
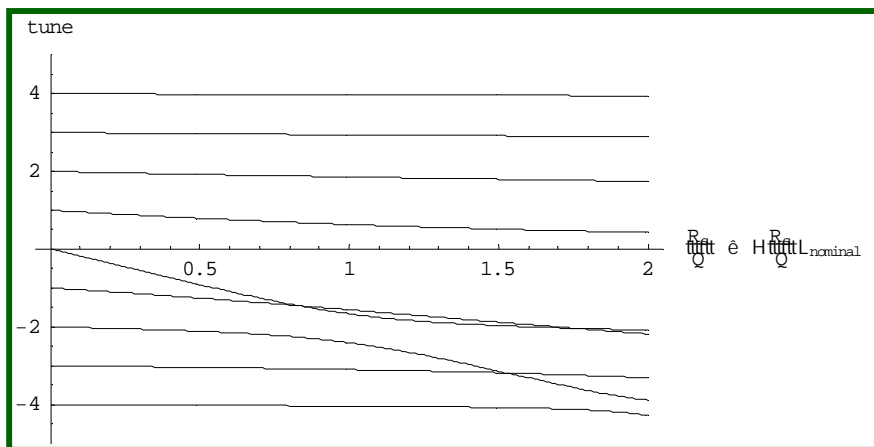




Electron Cloud



- Significant discussion at LC02, and ECLOUD02
- Studies for NLC by Sam Heifets, Mauro Pivi and Miguel Furman
- Single-bunch and coupled-bunch effects
- Still significant uncertainties
 - cloud density, distribution and dynamics
 - instability modes and models
- Simple analysis suggests NLC MDR:
 - is above (or at least close to) strong head-tail threshold
 - could experience coupled bunch growth times $\sim 20 \mu\text{s}$

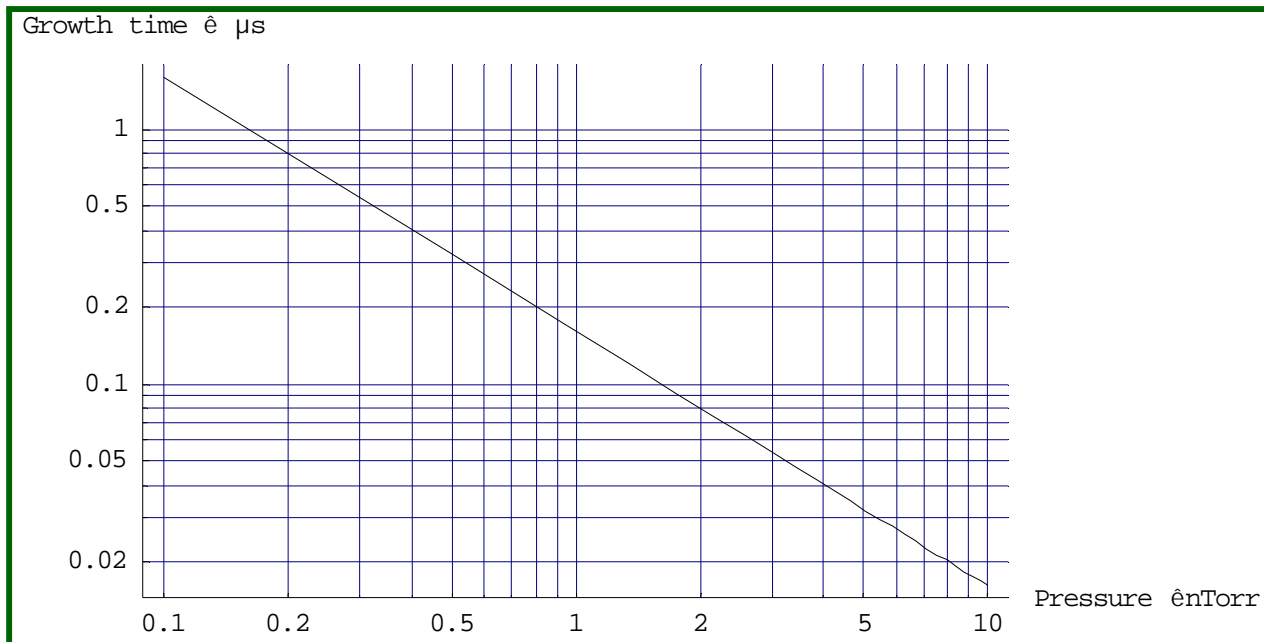




Fast Ion Instability



- Ions generated from residual gas interact with bunches further down the bunch train
- Oscillations can grow from Schottky noise
- Rise times can be fast, though growth strictly not exponential
- Some observations (ALS, PLS) though further verification is important

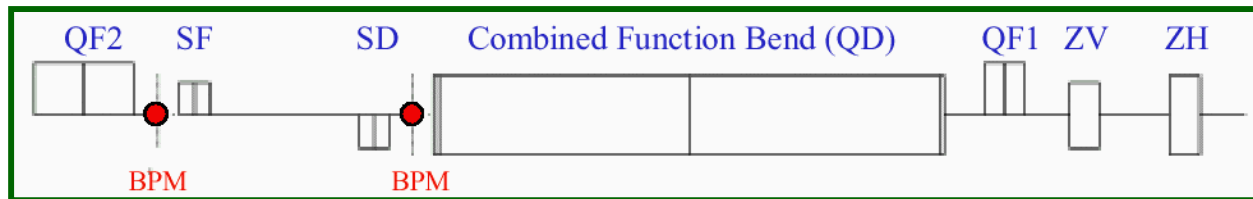




ATF



- Focus of recent work at the ATF has been on low emittance
 - achieving low emittance (alignment)
 - measuring low emittance (instrumentation)
- Beam-Based Alignment
 - Marc Ross, Mark Woodley, Janice Nelson
 - aim to measure BPM-quad offset to 20 μm
 - hope to reduce vertical emittance below 10 pm (20 pm achieved)



- use method of quadrupole variation
 - make a closed bump through target BPM-quadrupole
 - determine kick from quadrupole by fitting difference orbit resulting from trim; for a given bump, gradient of kick vs trim gives offset
 - plot offset vs BPM reading for different bumps, to determine BPM-quad offset

Thanks to Mark Woodley for permission to draw from his talk at LC02



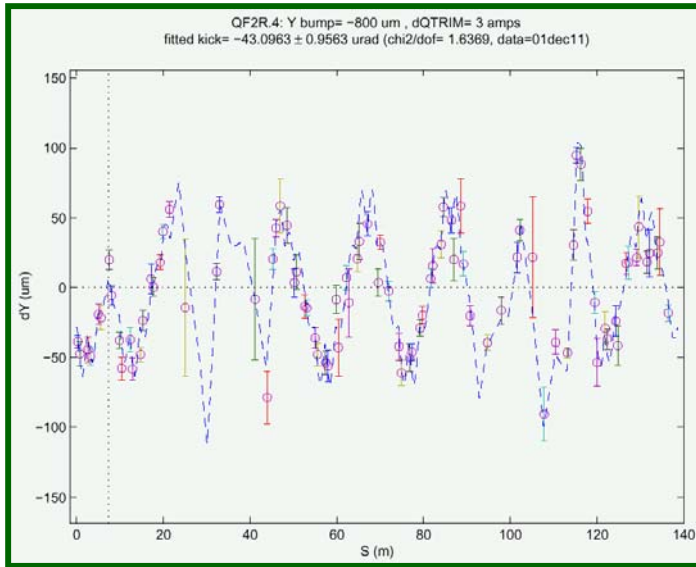
BBA Challenges



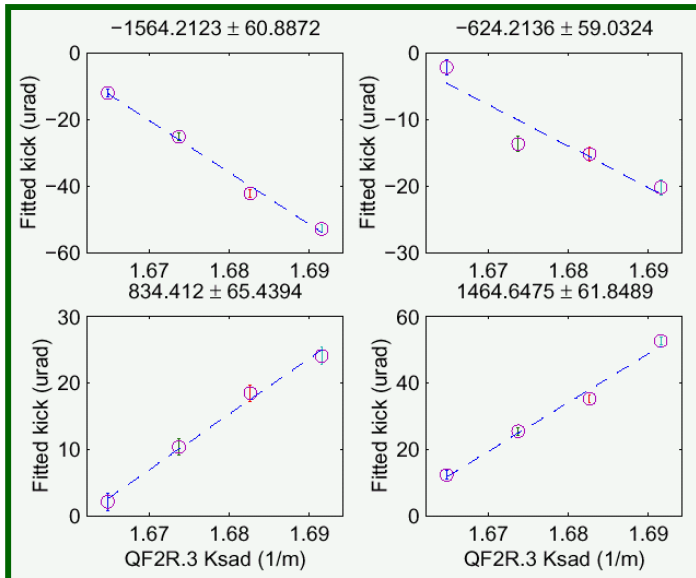
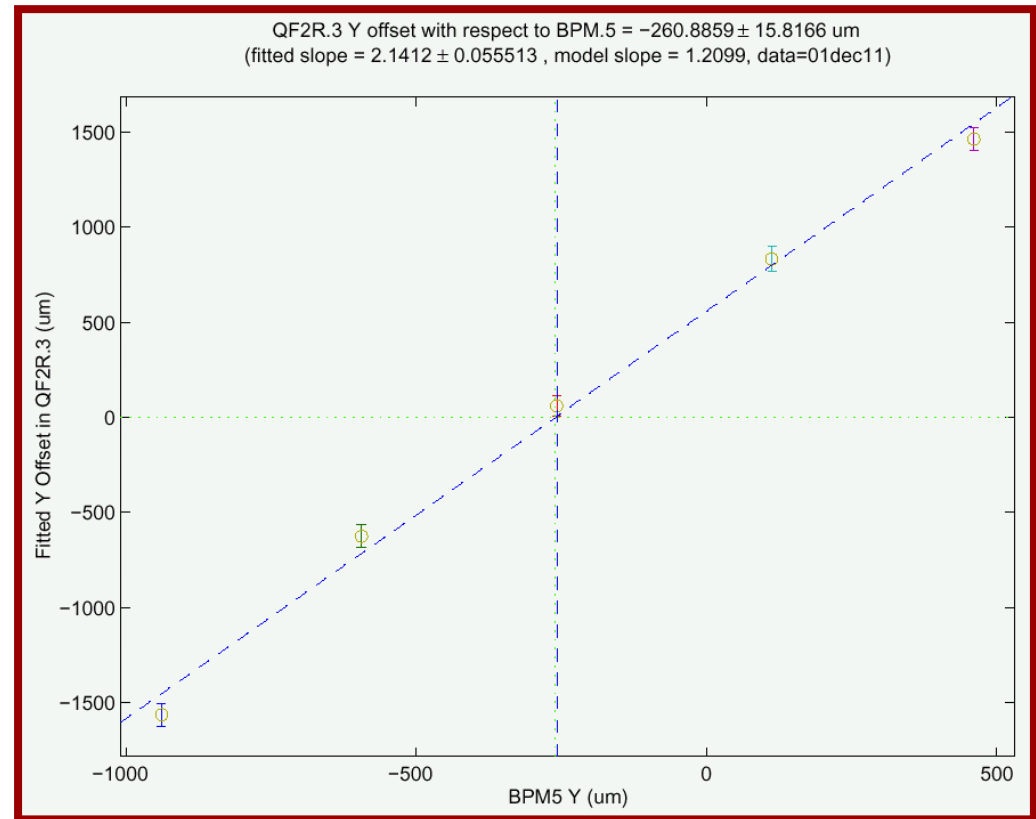
- Intensity dependence
 - affects BPM reading
 - affects BPM resolution
 - $20\text{ }\mu\text{m}$ at 10^{10} per bunch, $40\text{ }\mu\text{m}$ at 0.5×10^{10} per bunch
 - average over 20 orbits
 - monitor intensity stability
- BPMs affected by beam losses
 - limits ranges for bumps and trims
 - monitor intensity stability
- Energy dependence
 - dispersion (mostly horizontal) at BPMs
 - include energy error in orbit fits
- Time limitation
 - acquire orbits at 3 Hz machine rate
 - 20 orbits for 25 settings for 100 BPMs for 2 planes (10 hours)
 - automated data taking



BBA at ATF

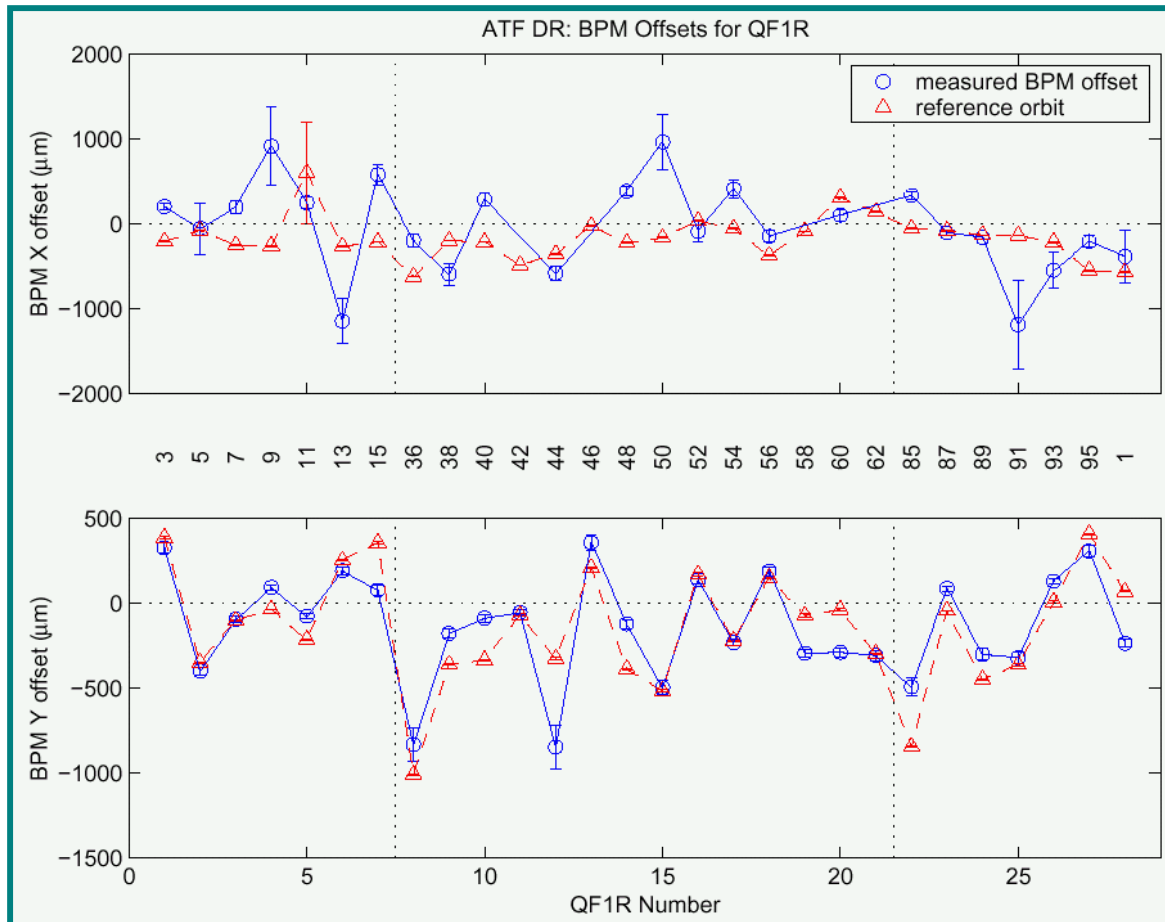


Example: BPM5Y reads -261 μm when beam has zero offset in QF2R.3



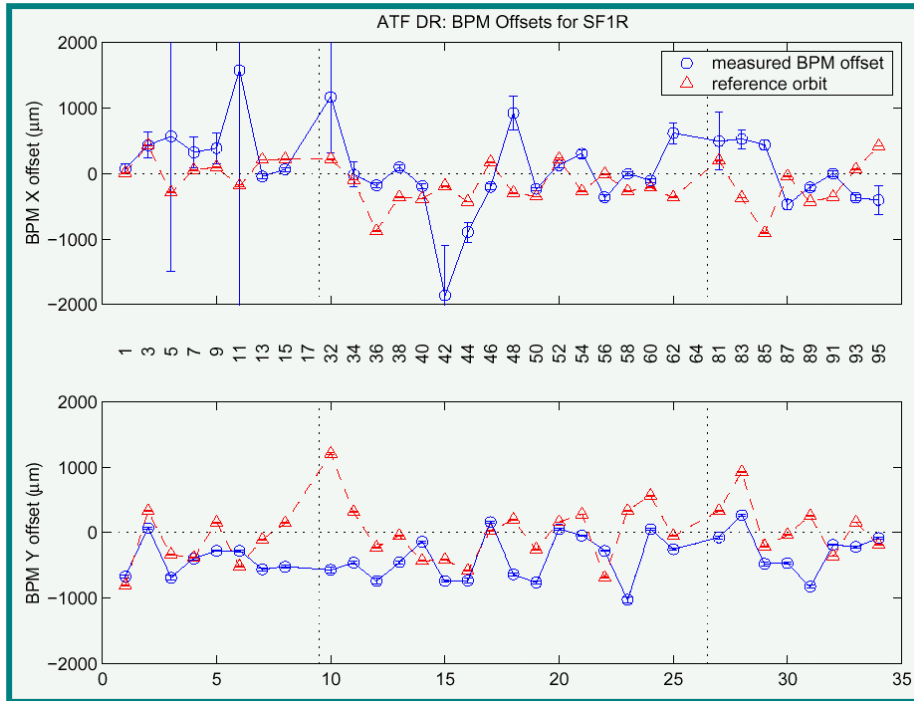
Note: We believe offsets are principally electronic in origin

BBA Quadrupole Results

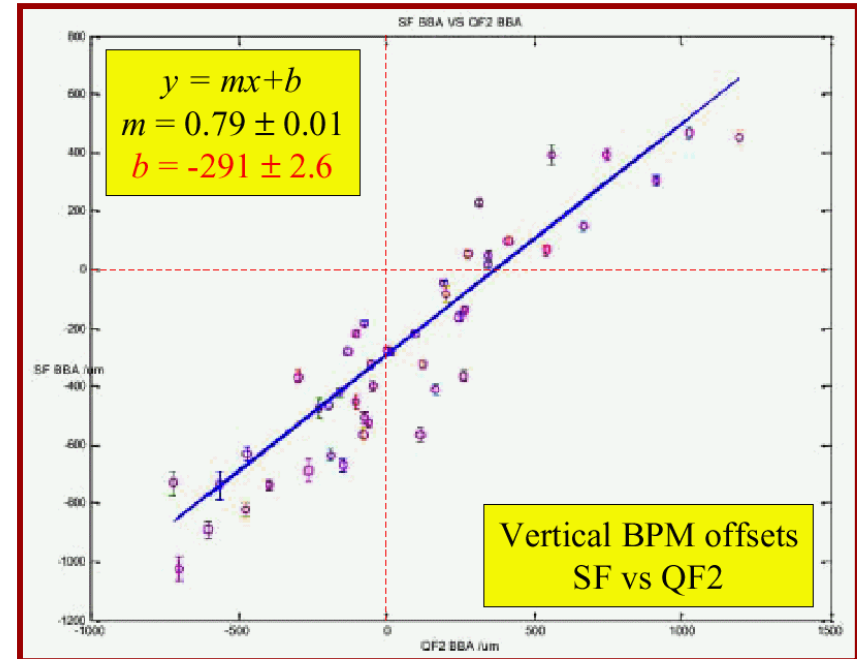


Low emittance tuning has found an orbit that minimizes vertical offset in the quadrupoles!

BBA Sextupole Results



- Low emittance reference orbit follows sextupole offsets to some extent.
- Note 300 μm systematic offset between quadrupoles and sextupoles.





ATF Recent Work



- Further BBA studies were performed in early March
 - Results for arc quadrupoles were reproducible
 - Turning off correctors steered beam through the quadrupole centers
 - ATF alignment is extremely good
 - Sextupole results were not as well reproducible
 - weak signal; hysteresis...
- Tests with skew correction using OTR and wire scanners
 - Even small errors in wire scanner measurements make it difficult in practice to determine vertical emittance and coupling
 - Data from OTR is extremely useful
 - It is currently believed that an imaging monitor of some kind will be required in the Damping Rings for effective tuning
 - There is now an active collaboration with DESY (TTF), to find the best OTR target material



Continuing BBA Work



- Complete measurements for all BPMs
 - include BPMs in the straights
 - iteration may improve results
- Use BBA data in constructing new reference orbit for low emittance tuning
- Understand origins of poor orbit fits
- Verify stability by repeating measurements
- Understand systematic offsets in quadrupole-sextupole alignment
 - systematics possibly introduced by differential pole saturation
- New BPM system
 - 2 μm resolution, scheduled for installation in November



Damping Rings R&D Program



- LC luminosity crucially dependent on Damping Rings performance
 - need to minimize uncertainties as much as possible
- High priority issues:
 - **Achieving Low Emittance**
 - Routine operation with very low vertical emittance still needs to be demonstrated
 - Continue work on BBA at ATF
 - Make use of other machines, e.g. SLS, SPRING8...
 - Some challenges for instrumentation/measurement
 - **Fast Ion Instability**
 - Verify theoretical predictions (e.g. by further work on ALS)
 - Develop simulation codes
 - **Electron Cloud**
 - Development of models and codes, to be able to make accurate predictions of cloud build-up and effects on the beam
 - Find the best way to prevent the cloud build-up (TiN...)
 - **Intra-Beam Scattering**
 - Need to fully understand ATF data and verify theory
 - Develop strategies to overcome limitation on the Damping Rings



Damping Rings R&D Program



- Other issues:
 - Nonlinear Dynamics
 - Improve dynamic aperture/momentum acceptance
 - Wiggler models
 - Beam-Radiation Interaction
 - Damping Ring wigglers provide an extreme regime
 - Injection Transients
 - Coupling between injected and stored trains
(e.g. through wake fields or feedback system)
 - Damping Time
 - Injection phase space mismatch from nonlinear distortion
 - Instrumentation
 - Especially for measuring low emittance beams
 - Kicker Compensation
 - Polarization